ICES CM 2011/D:04

Long term trends in population dynamics of NW Ireland herring revealed by data archaeology

Maurice Clarke, Afra Egan, Stefano Mariani and Dana Miller

Marine Institute, Rinville, Oranmore, Co. Galway, Ireland.
*Zoology Department, University College, Dublin 4, Ireland.
Contact: maurice.clarke@marine.ie. Tel. 00 353 91 387 200, Fax: 00 353 91 387 201.

Abstract

Herring populations to the northwest of Ireland are considered to constitute a single stock. They consist of a diverse array of autumn, winter and spring spawning components. They have been subject to large catches in the past. Landings peaked at 50 000 t in 1987 and have shown a slow decline since, as 2 dominant year classes, born in the 1980s, declined. No strong year classes have appeared since, and the stock is now outside safe biological limits. The time series of data available for stock assessment only covered the period 1970- present, even though routine sampling began after the end of World War I. In order to examine the stock trajectories over time, all catch at age data for the period 1921-1970 were compiled and analysed. The study revealed large fluctuations in the size of the stock and its productivity over time. Occasional strong cohorts occurred either singly, or in close together within 5 years of each other, and were observed at roughly 20-40 year intervals. Interspersed with this were long intervals of poor recruitment. Further historical analyses of 18th and 19th century records confirm this general periodicity. Overall results were examined in the context of time series of sea surface temperature data. The study can provide a basis for development of a long term management plan for the stock, using management strategy evaluation (MSE). The implications of this work, for the rational management of this stock for the future, are discussed.

Keywords: herring, northwest Ireland, catch-at-age, productivity, historical analyses

Contact author: Maurice Clarke, Marine Institute, Rinville, Oranmore, Co. Galway, Ireland. Tel. 00 353 91 387 200, Fax: 00 353 91 387 201, Email: maurice.clarke@marine.ie

Introduction

Atlantic herring, *Clupea harengus* L., populations north and west of Ireland consists of autumn, winter and spring spawning components. Populations in ICES Division VIa(south) and Divisions VIIb and VIIc are considered to comprise a single stock, see Figure 1. Before 1982, all herring in Division VIa were assessed together, but were thereafter separated for assessment and management purposes. This was based on differing stock dynamics and the realisation that there were discrete spawning components in each area (ICES, 1981).

ICES working groups have considered this herring stock since early 1970s. The time series of data available for stock assessment only covered the period 1970- present, even though catch at age data were available for the period 1957-1969, partly from the old combined VIa assessments, conducted prior to 1982. In addition, routine biological sampling of catches was performed from 1921 to 1947, though these data have never been collated.

Reported landings peaked at 50 000 t in 1987 and have shown a slow decline since, as 2 dominant year classes, born in the 1980s, declined. No strong year classes have appeared since, and the stock is

now considered to be outside safe biological limits. Recent ICES advice has consistently been that fishing should not proceed without a rebuilding plan being put in place (ICES, 2011). It is the purpose of this short study, to collate previous data to extend the time series available for stock assessment. From this it is possible to obtain a better knowledge of the dynamics of the stock over a longer period, and to understand its current state in a better historic context.

Materials and methods

Data reconstruction 1888-1956

Catch (by weight) data were available from the Reports of Sea and Inland Fisheries for Ireland (1888-1956), ICES *Bulletin Statistique* (1903-1956), which were also available online on the ICES website, and were cross-referenced as a quality check. The best estimates of catches by year for the area corresponding to the modern stock area were compiled according to the text table below, and are presented in Figure 2.

Years	Country	Reference
1888-1903	All	Sea and Inland Fisheries Reports (Ireland)
1903-1956	Ireland, UK	Sea and Inland Fisheries Reports (Ireland)
1903-1956	Belgium, France, Germany, Netherlands	ICES *Bulletin Statistique*

The Sea and Inland Fisheries Reports (Ireland) landings agree with the data reported to ICES. It is known that the Irish statistics reported to ICES included foreign landings (ICES, 1929). The Scottish and English *Bulletin Statistique* could not be used, because it was impossible to segregate them according to modern stock area. The Sea and Inland Fisheries Reports (Ireland) are thought to represent the vast majority of Irish and UK catches from the stock. European continental country catches from *Bulletin Statistique* were used, because there is no record in the literature of these vessels landing into Ireland. Only in the period 1928 to 1938 were catches from continental countries substantial, and from 1930-1938 they greatly exceeded the Irish and UK catches combined.

Catch in numbers at age (winter rings) was available from the reports of the Dove Marine Laboratory for the years 1921-1939. These samples were from landings into Irish ports, representing fisheries either for autumn or spring fisheries. It is accepted that the autumn spanners taken in the "harvest fishery" are separate from the spring component (Farran, 1937), so an attempt was made to allocate samples to catches of each component separately. It was difficult to allocate these samples to the appropriate landings because separate catch data are not available for the two components. The best approach was considered to be to use the proportion of samples of each component in a given year. This approach makes the best use of both types of samples. Also, it was recognised that there was a significant positive regression between landings per year and number of samples. This suggests that the number of samples is related to the quantity of landings.

Data reconstruction 1957-1969

The following data were available for this period:

Catch-numbers-at-age	VIa	1957-1980	(ICES, 2004)
Catch in tones	VIa (south of 57^{o}N)	1967-1980	(ICES, 1978)

VIIbc 1970-1980 (ICES, 1981).

The data presented in HAWG 1978 could not be used because they were for the area south of 57°N, rather than south of 56°N, not corresponding to the modern spatial assessment unit. The methods by which these data were compiled and collated are presented in ICES 2011, Annex 7.

A population model was produced by combining these data with the data used by ICES. The methods by which this was conducted are described in ICES (2011). The separable Virtual Population Analysis (sVPA) (Darby and Flatman, 1994) was used as this is currently the standard procedure for this stock. Based on the results of this, a stock recruitment relationship was fitted using a segmented regression and Julio's algorithm. Data from the non-converged VPA were excluded, following standard procedures used by ICES. The model was fitted with and without the exceptionally strong cohorts.

Results and Discussion

The best estimate of catch in tonnes estimated for VIaS and VIIbc over the time series is presented in Figure 2. It can be seen that catches exceeded the long term mean only in the period 1910-1912 and in 1928. However they exceeded the mean again in 1966 remaining above until 2008. ICES (2011) considered that German Democratic Republic (East German) landings in VIaS may be underestimated. However the current archival work and an analysis of the data available from the ICES website show no records of GDR having fished this stock.

The catch data are considered to be inaccurate. There are a number of reasons for assuming this. It was not possible to distinguish UK landings to UK ports 1888-1949 by stock area. Using landings into Ireland is the best approach possible, but it is likely that some UK landings to UK ports are unaccounted for. English trawlers from Fleetwood were known to catch herring in the "Klondyke" ground, that straddles the modern boundary with the VIaN herring stock (Le Gall, 1926). Yet these catches do not appear in any of the landings statistics for UK ports. A proportion of these may have been landed into Ireland, and if so, they are captured in the current study. However it is unclear to what extent these vessels landed into Ireland. It is also not clear if European continental vessels (Belgian, French, German and Dutch) landed into Ireland, if at all, during this period. However there are no records of such landings. If they did land into Ireland, then the current study data are overestimated.

A striking feature of the archival data from the 1930s was the quantity of landings by French vessels. French statistics are unavailable before 1928. In that year 127 t was reported, and this increased in an almost linear fashion to over 9,600 t by 1938, after which no catches were reported. Much of these catches were reported from VIIbc. It is likely that a proportion of these catches are of the neighbouring Celtic Sea and VIIj stock, but the extent of this is unknown.

The catch at age data for the extended modern series (1957-2010) are presented in Figure 3. The well-documented 1981 and 1995 cohorts are clearly visible, but the 1963 cohort also appears exceptionally strong. The strength of this cohort was noted by Bracken and Phillips (1970), though was subsequently overlooked by ICES. The extended modern population assessment, presented in Figure 4 is not a good indicator of current stock status, but in the converged period shows the development of the stock. The increase in catches to above the long term mean, in 1966, was driven by the 1963 cohort. This cohort had disappeared from the fishery by the mid 1970s and no similarly strong cohort replaced it. However catches remained well above the mean for many years after that. During the 1970s catches continued to increase, as the fishing fleet developed (Molloy, 2006), recruitment

fluctuated at a lower level and fishing mortality increased markedly to over 0.5 (Figure 4). The return of high recruitment in the 1980s sustained the high catches until the early 1990s. Since then F has remained very high and the stock fell to low levels as catches remained well above the long term mean.

The re-constructed catch at age data for the period 1921-1935 are presented in Figure 5. The data for 1937-1939 are based on few samples, mainly of autumn spawners and are not considered a good indicator of overall age structure. These data provide further information on recruitment cycles. It is very clear that the 1914, 1920, 1924 and 1925 year classes were strong. Farran (1930) produced an analysis of these data showing the same pattern of recruitment (Figure 6). The very high catches in the first decade of the 20th century were surely associated with exceptional recruitment, and Storrow (1922) considered that the strongest year class in that earlier period was that of 1906.

Apart from the 1930 cohort recruitment seems to have been weak from 1926 onwards, and the stock can be considered to have declined. When the large French catches, of the 1930s are included it seems reasonable to assume that overall fishing mortality on the stock must have been quite high, at a time of such low recruitment.

For the period before 1888 comprehensive catch statistics are not available. However from reports contained in two enquiries into the state of Irish fisheries (Commission of Enquiry. 1836; 1886) it is noted that the following periods were associated with outstanding herring fisheries:

- 1773 - 1783
- 1808 – 1816
- 1830s
- 1850s
- 1880s/1890s

It may be assumed that these coincided with periods of good recruitment.

Grainger (1978; 1980) found significant negative correlations between sea surface temperature (SST) and catches from the west of Ireland component of this stock at a time lag of 3-4 years later. This indicates that recruitment responds favourably to cooler temperatures. Cannaby and Hosrevoglu (2009) present long time series of sea surface temperature for this stock area. In Figure 7 these data are combined with periods of good recruitment. It can be seen that the strong herring recruitments/fisheries correspond with cooler temperatures.

The stock recruitment relationships displayed in Figure 8 indicate recruitment impairment at SSB of about 76,000 t or 79,000 t, corresponding to low-only or low/high recruitment regimes. This suggests that a suitable limit biomass reference point could be set at about 76,000 t. SSB below this can be considered associated with risk of recruitment impairment.

From a study of the history of this stock over the past two centuries, it is possible to place the current understanding of stock status in a better context. Although the current status is uncertain, even the most optimistic assessment run shows the stock to be at risk of low recruitment. Recent recruitment since the mid 1990s has been estimated to be low. There is limited information on recruitment in the assessments available, there is no evidence of any having been above average. Historical analyses suggest that good recruitments only occur during cold periods, and the recent years have coincided with a warm period. Elevated productivity (good recruitment) is not only associated with cooler temperatures, but also with SSB > 60,000 t.

In earlier years high catches only occurred during periods of high productivity. Since the 1960s there have been very high catches, even when recruitment was low. This has led to very high F (long term mean = 0.43, since 1970s). This is much higher than the best estimate of F_{msy} (0.25) considered by ICES (ICES, 2011. The combination of high F preventing recovery during an unfavourable climatic period for the stock and a stock size below the level associated with recruitment impairment, all imply a stock that is in need of rebuilding measures. The first step in achieving rebuilding of the stock will be to reduce F substantially from recent rates. But rebuilding will be slower if conditions associated with low recruitment continue.

Acknowledgements

The various people who collected samples from the fisheries over the years are gratefully acknowledged: Willie Moore (Fish Processor, Buncrana, 1920s and 1930s); George Farran (Irish Department of Fisheries, 1920s-1940s); Benjamin Storrow and Dorothy Cowan (Dove Marine Laboratory, Newcastle, UK, 1920s-1940s); John Molloy, Dermot Kennedy, John Bracken and Eugene Mullins (Irish Marine Institute and its predecessors,1950s-present). John Simmonds and Steve Kelts of Marine Scotland Laboratory, Aberdeen, made the reconstruction of the data for 1957-1969 easier by having extracted the modern VIaN catch at age from the old VIa data. The MI library team of Anne Wilkinson and Fintan Bracken, along with the ICES Librarian assisted in obtaining archive reports and data.

References used for data retrieval

<u>Sea and Inland Fisheries Reports (Ireland)</u>

Department of Agriculture and Technical Instruction for Ireland, 1901. Report on the Sea and Inland Fisheries for the year 1900.

Department of Agriculture and Technical Instruction for Ireland, 1902. Report on the Sea and Inland Fisheries for the year 1901.

Department of Agriculture and Technical Instruction for Ireland, 1903. Report on the Sea and Inland Fisheries for the year 1902.

Department of Agriculture and Technical Instruction for Ireland, 1904. Report on the Sea and Inland Fisheries for the year 1903.

Department of Agriculture and Technical Instruction for Ireland, 1905. Report on the Sea and Inland Fisheries for the year 1904.

Department of Agriculture and Technical Instruction for Ireland, 1906. Report on the Sea and Inland Fisheries for the year 1905.

Department of Agriculture and Technical Instruction for Ireland, 1907. Report on the Sea and Inland Fisheries for the year 1906.

Department of Agriculture and Technical Instruction for Ireland, 1908. Report on the Sea and Inland Fisheries for the year 1907.

Department of Agriculture and Technical Instruction for Ireland, 1909. Report on the Sea and Inland Fisheries for the year 1908.

Department of Agriculture and Technical Instruction for Ireland, 1910. Report on the Sea and Inland Fisheries for the year 1909.

Department of Agriculture and Technical Instruction for Ireland, 1911. Report on the Sea and Inland Fisheries for the year 1910.

Department of Agriculture and Technical Instruction for Ireland, 1912. Report on the Sea and Inland Fisheries for the year 1911.

Department of Agriculture and Technical Instruction for Ireland, 1913. Report on the Sea and Inland Fisheries for the year 1912.

Department of Agriculture and Technical Instruction for Ireland, 1914. Report on the Sea and Inland Fisheries for the year 1913.

Department of Agriculture and Technical Instruction for Ireland, 1915. Report on the Sea and Inland Fisheries for the year 1914.

Department of Agriculture and Technical Instruction for Ireland, 1916. Report on the Sea and Inland Fisheries for the year 1915.

Department of Agriculture and Technical Instruction for Ireland, 1917. Report on the Sea and Inland Fisheries for the year 1916.

Department of Agriculture and Technical Instruction for Ireland, 1918. Report on the Sea and Inland Fisheries for the year 1917.

Department of Agriculture and Technical Instruction for Ireland, 1919. Report on the Sea and Inland Fisheries for the year 1918.

Department of Agriculture and Technical Instruction for Ireland, 1920. Report on the Sea and Inland Fisheries for the year 1919.

Department of Agriculture and Technical Instruction for Ireland, 1921. Report on the Sea and Inland Fisheries for the year 1920.

Department of Agriculture and Technical Instruction for Ireland, 1923. Report on the Sea and Inland Fisheries for the year 1921.

Department of Fisheries, 1927. Report on the Sea and Inland Fisheries for the years 1923, 1924 and 1925.

Department of Lands and Fisheries, 1930. Report on the Sea and Inland Fisheries for the years 1926, 1927 and 1928.

Department of Lands and Fisheries, 1933. Report on the Sea and Inland Fisheries for the years 1929 and 1930.

Department of Lands and Agriculture, 1935. Report on the Sea and Inland Fisheries for the years 1931, 1932 and 1933.

Department of Agriculture, 1936. Report on the Sea and Inland Fisheries for the year 1934.

Department of Agriculture, 1936. Report on the Sea and Inland Fisheries for the year 1935.

Department of Agriculture, 1937. Report on the Sea and Inland Fisheries for the year 1936.

Department of Agriculture, 1938. Report on the Sea and Inland Fisheries for the year 1937.

Department of Agriculture, 1940. Report on the Sea and Inland Fisheries for the year 1938.

Department of Agriculture, 1941. Report on the Sea and Inland Fisheries for the year 1939.

Department of Agriculture, 1941. Report on the Sea and Inland Fisheries for the year 1940.

Department of Agriculture, 1943. Report on the Sea and Inland Fisheries for the year 1941.

Department of Agriculture, 1943. Report on the Sea and Inland Fisheries for the year 1942.

Department of Agriculture, 1944. Report on the Sea and Inland Fisheries for the year 1943.

Department of Agriculture, 1945. Report on the Sea and Inland Fisheries for the year 1944.

Department of Agriculture, 1946. Report on the Sea and Inland Fisheries for the year 1945.

Department of Agriculture, 1947 Report on the Sea and Inland Fisheries for the year 1946.

Department of Agriculture, 1948. Report on the Sea and Inland Fisheries for the year 1947.

Department of Agriculture, 1950. Report on the Sea and Inland Fisheries for the year 1948.

Department of Agriculture, 1950. Report on the Sea and Inland Fisheries for the year 1949.

Department of Agriculture, 1951. Report on the Sea and Inland Fisheries for the year 1950.

Department of Agriculture, 1952. Report on the Sea and Inland Fisheries for the year 1951.

Department of Agriculture, 1953. Report on the Sea and Inland Fisheries for the year 1952

Department of Agriculture, 1954. Report on the Sea and Inland Fisheries for the year 1953.

Department of Agriculture, 1955. Report on the Sea and Inland Fisheries for the year 1954.

Department of Agriculture, 1956. Report on the Sea and Inland Fisheries for the year 1955.

Department of Agriculture, 1957. Report on the Sea and Inland Fisheries for the year 1956.

Inspectors of Irish Fisheries. 1889. Report on the Sea and Inland Fisheries for the year 1888.

Inspectors of Irish Fisheries. 1890. Report on the Sea and Inland Fisheries for the year 1889.

Inspectors of Irish Fisheries. 1891. Report on the Sea and Inland Fisheries for the year 1890.

Inspectors of Irish Fisheries. 1892. Report on the Sea and Inland Fisheries for the year 1891.

Inspectors of Irish Fisheries. 1893. Report on the Sea and Inland Fisheries for the year 1892.

Inspectors of Irish Fisheries. 1894. Report on the Sea and Inland Fisheries for the year 1893.

Inspectors of Irish Fisheries. 1895. Report on the Sea and Inland Fisheries for the year 1894.

Inspectors of Irish Fisheries. 1896. Report on the Sea and Inland Fisheries for the year 1895.

Inspectors of Irish Fisheries. 1897. Report on the Sea and Inland Fisheries for the year 1896.

Inspectors of Irish Fisheries. 1898. Report on the Sea and Inland Fisheries for the year 1897.

Inspectors of Irish Fisheries. 1899. Report on the Sea and Inland Fisheries for the year 1898.

Inspectors of Irish Fisheries. 1900. Report on the Sea and Inland Fisheries for the year 1899.

Ministry of Fisheries, 1925. Report on the Sea and Inland Fisheries for the year 1922.

ICES "*Bulletin Statistique*"

ICES, 1911. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1908. Volume V.

ICES, 1912. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1909. Volume VI,

ICES, 1914. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1910. Volume VII.

ICES, 1917. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'années 1911, 1912. Volume VIII

ICES, 1919. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1913. Volume IX

ICES, 1922. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'années 1914-1918. Volume X.

ICES, 1924. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'années 1919-1920. Volume XI.

ICES, 1925. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'années 1921-1922. Volume XII.

ICES, 1926. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1923. Volume XIII.

ICES, 1927. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1924. Volume XIV.

ICES, 1927. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1925. Volume XV.

ICES, 1928. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1926. Volume XVI.

ICES, 1929. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1927. Volume XVII.

ICES, 1930. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1928. Volume XVIII.

ICES, 1931. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1929. Volume XIX.

ICES, 1932. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1930. Volume XX.

ICES, 1933. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1931. Volume XXI.

ICES, 1934. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1932. Volume XXII.

ICES, 1935. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1933. Volume XXIII.

ICES, 1936. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1934. Volume XXIIIV.

ICES, 1937. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1935. Volume XXV.

ICES, 1938. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1936. Volume XXVI.

ICES, 1939. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1937. Volume XXVII.

ICES, 1944. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1938. Volume XXVIII.

ICES, 1947. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1939. Volume XXIX.

ICES, 1949. Bulletin Statistique des Pêches Maritimes des Pays du Nord del'Europe pour l'année 1940-1944. Volume XXX.

ICES Herring Assessment Working Group Reports: "HAWG"

ICES. 1978. Report of the Herring Assessment Working Group South of 62ºN. Copenhagen: ICES CM 1979/H:03. 74 pp.

ICES. 1981. Report of the Herring Assessment Working Group South of 62ºN. Copenhagen: ICES CM 1981/H:08. 120 pp.

ICES, 2004. Report of the Herring Assessment Working Group South of 62ºN. Copenhagen: ICES 2004/ACFM: 18. 551 pp.

"Dove Marine Laboratory Reports"

Storrow, B. 1922. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1922. pp. 11-43.

Storrow, B. 1923. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1922. pp. 8-40.

Storrow, B. 1924. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1924. pp. 8-30.

Storrow, B. 1925. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1925. pp. 8-14.

Storrow, B. 1926. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1926. pp. 8-19.

Storrow, B. 1927. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1927. pp. 9-22.

Storrow, B. 1929. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1928. pp. 9-31.

Storrow, B. 1929. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1929. pp. 9-33.

Storrow, B. 1931. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1930. pp. 9-31.

Storrow, B. 1931. Herring shoals. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1931. pp. 8-26.

Storrow, B. and Cowan, D 1933. Herring investigations. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1932. pp. 11-30.

Storrow, B. and Cowan, D. 1934. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1933. pp 9-21

Storrow, B. and Cowan, D. 1935. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1934. pp 9-22.

Storrow, B. and Cowan, D. 1936. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1935. pp 11-26.

Storrow, B. and Cowan, D. 1937. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1936. pp 10-32.

Storrow, B. and Cowan, D. 1938. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1937. pp 10-18.

Storrow, B. and Cowan, D. 1936. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1938. pp 12-22.

Storrow, B. and Cowan, D. 1936. Herring investigations. In. Anon. Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending July 31st 1939. pp 7-16.

General References

Bracken, J. and Phillips, D. R. 1970. Donegal herring investigations 1967/68. The Scientific Proceedings of the Royal Dublin Society - Series B 2, 233 - 249.

Cannaby, H. and Husrevoglu, Y. S. 2009 The influence of low-frequency variability and long-term trends in North Atlantic sea surface temperature on Irish waters. ICES Journal of Marine Science. 66, 1480-1489.

Darby, C.D., Flatman, S., 1994. Virtual population analysis: version 3.1 (Windows/DOS) user guide. MAFF Information Technology Series No.1. Directorate of Fisheries Research: Lowestoft.

Farran, G. P. 1930. Fluctuations in the stock of herrings on the north coast of Donegal. Rapports Et Proces-Verbaux Des Reunions Du Conseil Permanent International Pour L'Exploration De La Mer 65, 6 pp.

Farran, G. P. 1937. The herring fisheries off the north coast of Donegal. Department of Agriculture Journal 34, 11 pp.

Grainger, R. J. 1978 A study of herring stocks west of Ireland and their oceanographic conditions. Unpublished PhD. Thesis. Galway: National University of Ireland. 262 pp.

Grainger, R. J. 1980. Irish west coast herring fluctuations and their relation to oceanographic conditions. ICES Marine Science Symposium on the Biological Basis of Pelagic Stock Management No 29., pp. 19.

ICES, 2011. Report of the Herring Assessment Working Group South of 62ºN. Copenhagen: ICES 2011/ACFM: 763 pp.

Commission of Inquiry. 1836. First Report of Commission of Inquiry into the State of Irish Fisheries.. Dublin. HM. Stationary Office.

Commission of Inquiry. 1886. Report of Commission of Inquiry into the State of Irish Fisheries. Dublin. HM. Stationary Office.

Le Gall, J. 1926. Études diverses sur le question du hareng. Notes et Raports 48. Paris: Office Secientifique et Techinque de Pêche Maritime. 67 pp.

Molloy, J. 2006. Irish Herring Fisheries 1900-2005, Biology, Research Development and Assessment. Galway: Marine Institute. 234 pp.

Storrow, B. 1922. Notes suggestive of further work in herring investigations. In. Meek, A. (ed.). Dove Marine Laboratory, Cullercoats, Northumberland, Report for the year ending June 30th 1922. pp. 57-91

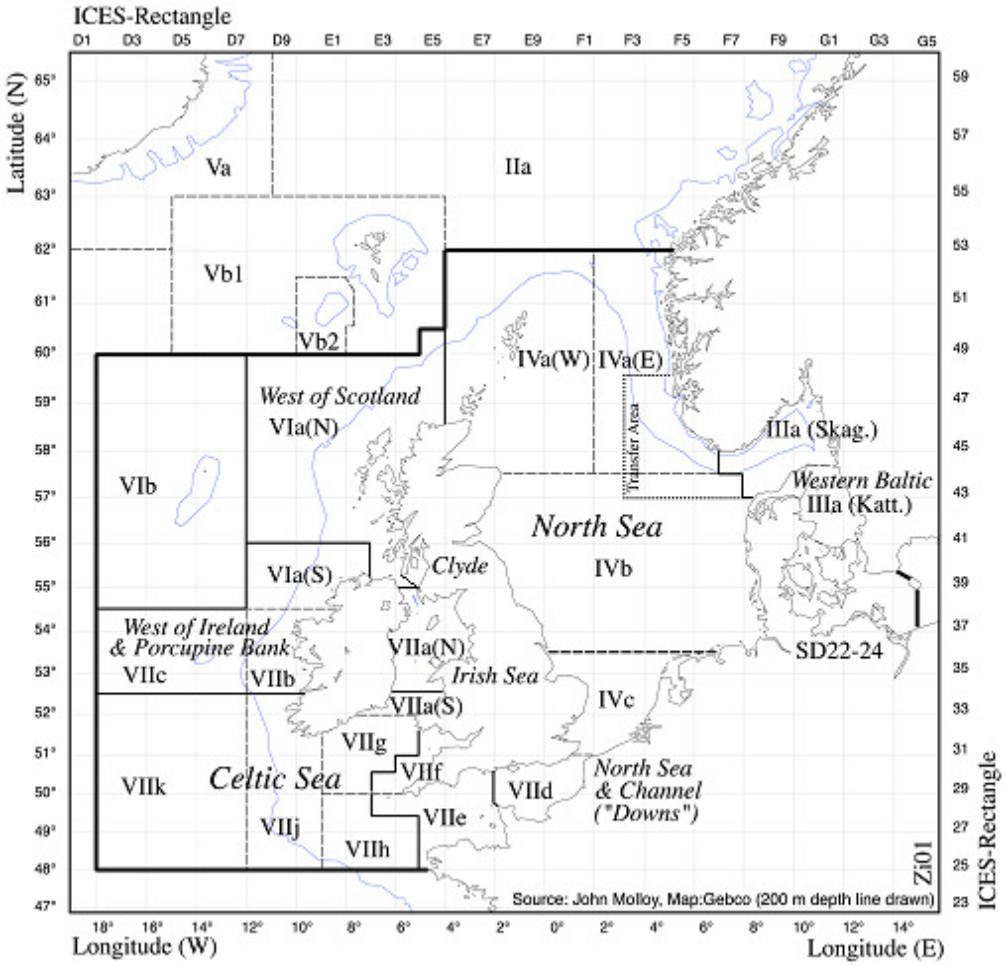

Figure 1. ICES areas as used for the assessment of herring stocks south of 62°N. reproduced.

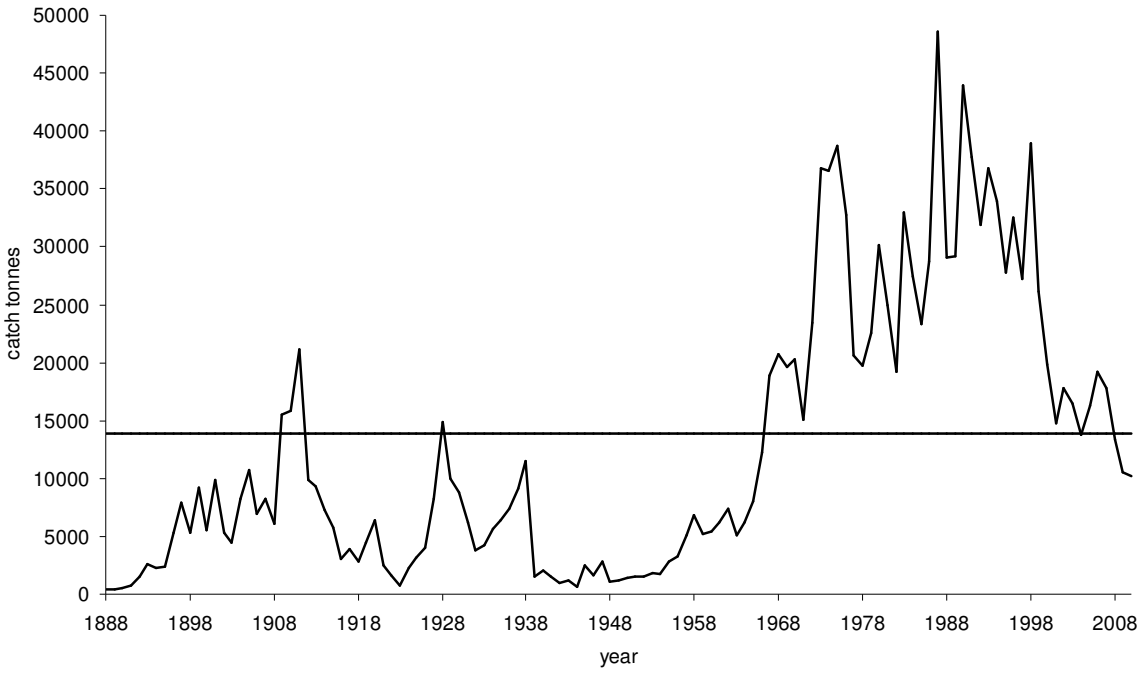

Figure 2. Best estimate of international catch (tonnes) since 1888 for herring in the area corresponding to VIaS and VIIbc. Long term average catch indicated.

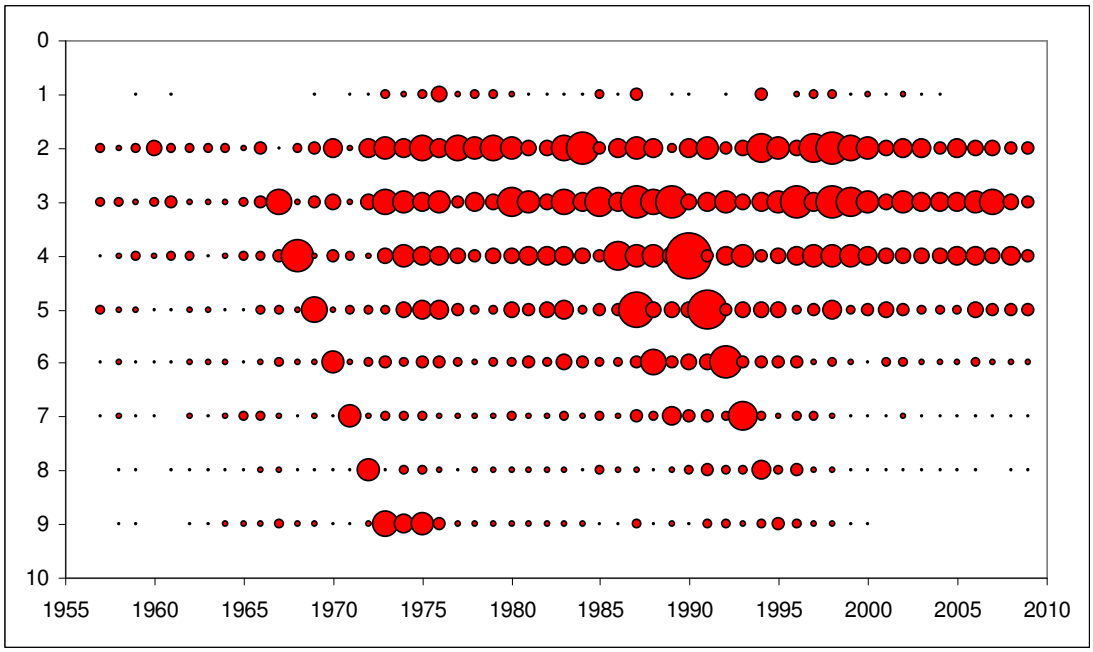

Figure 3. Bubble plot of catch numbers at age for 1957-2010 time series of herring in VIaS and VIIbc.

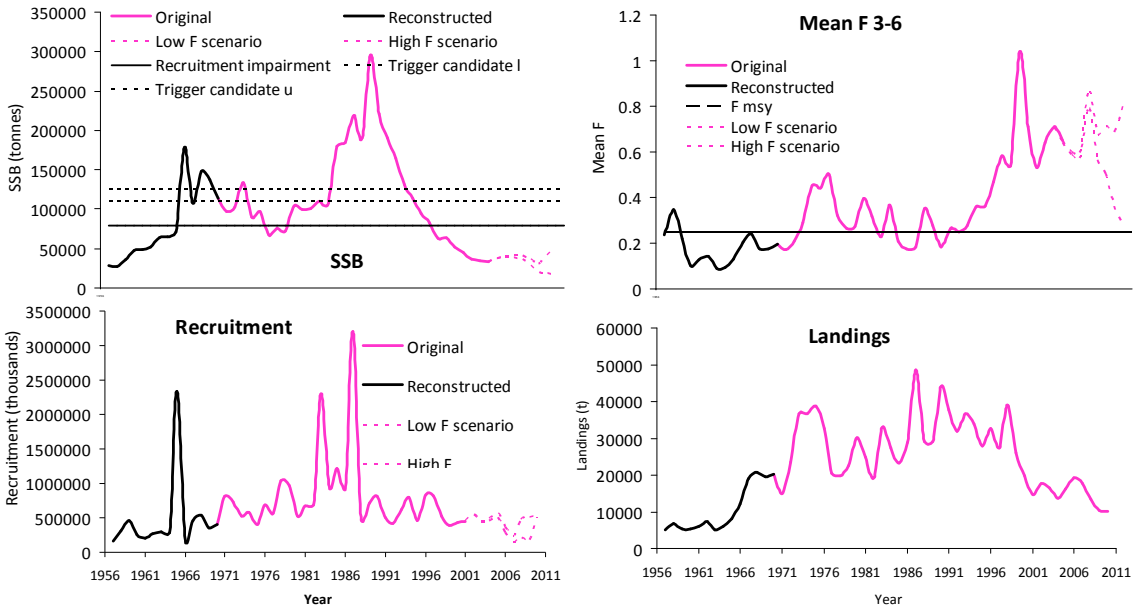

Figure 4. Results of population modelling for period 1957-2011. Clockwise from top left, spawning stock biomass (SSB), mean fishing mortality (F) over 3-6 winter ring, best estimate of catch (landings) and recruitment at 1 winter ring.

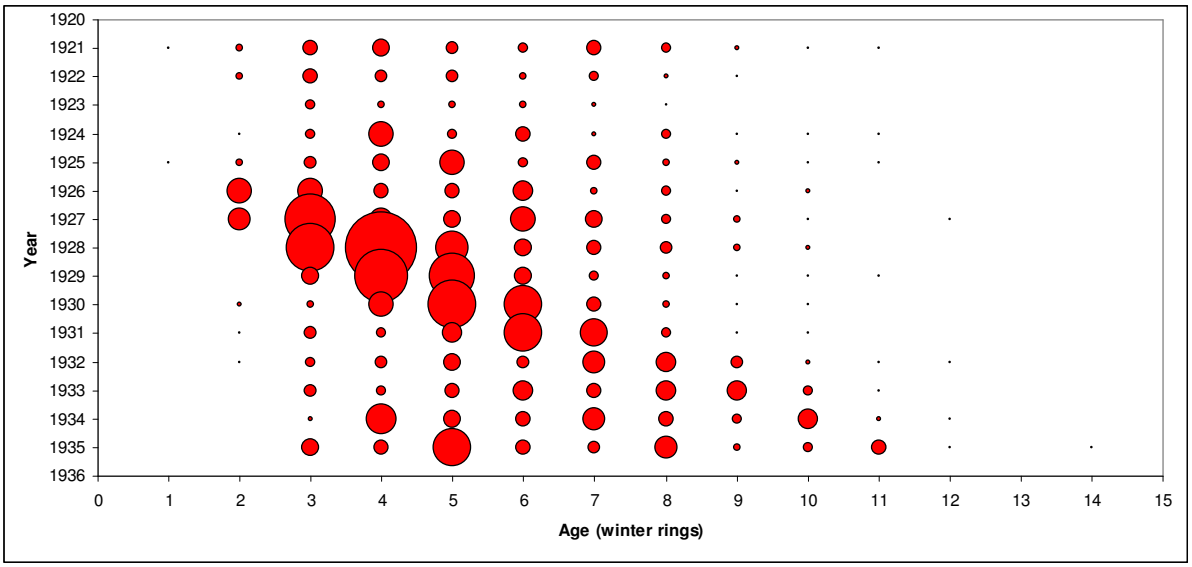

Figure 5. Bubble plot of catch numbers at age for 1921-1936 time series of herring in VIaS and VIIbc.

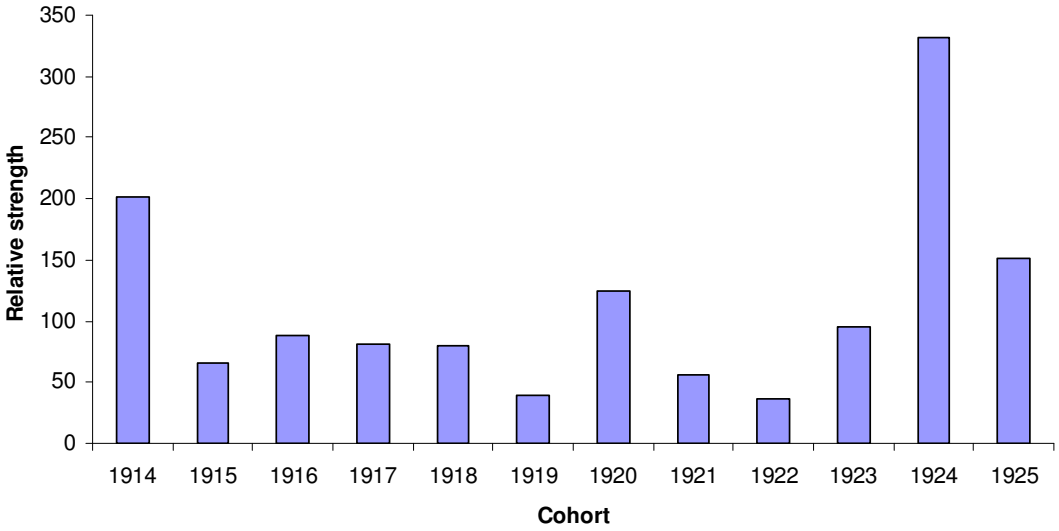

Figure 6. Relative strength of cohorts hatched between 1914 and 1925, from analyses conducted by Farran (1930).

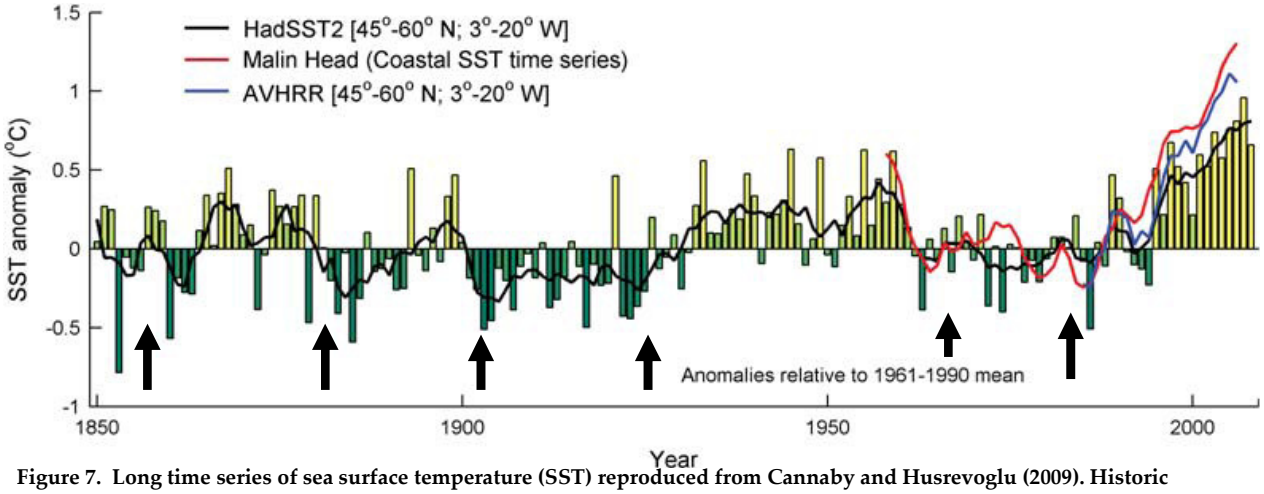

Figure 7. Long time series of sea surface temperature (SST) reproduced from Cannaby and Husrevoglu (2009). Historic instances of high recruitment and/or large fisheries are indicated by arrows.

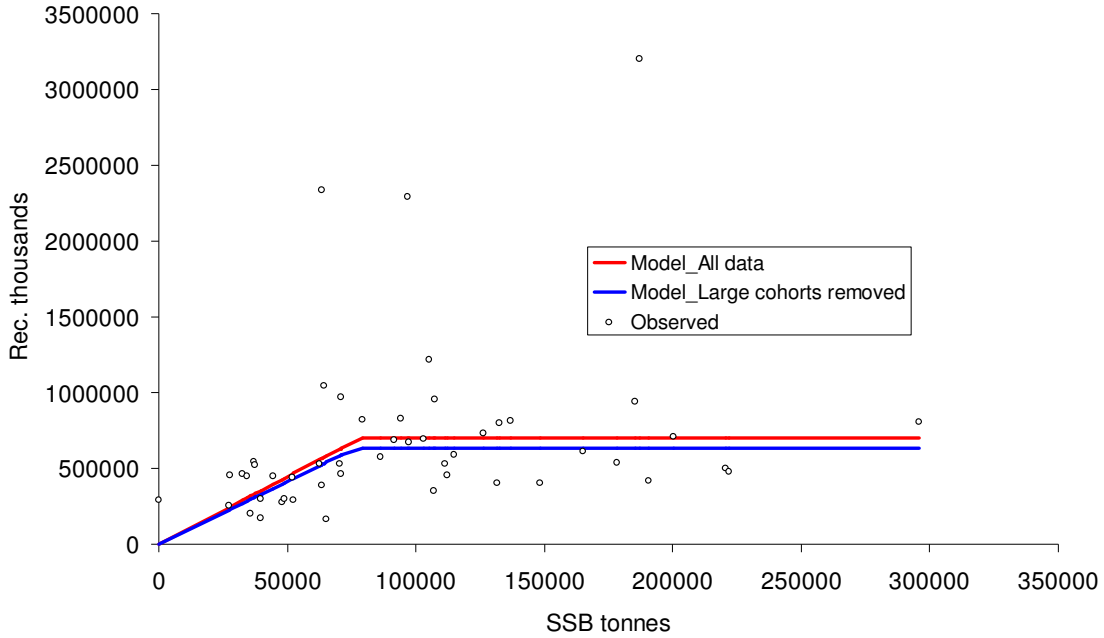

Figure 8. Stock recruitment relationship, fitted using a segmented regression and Julio's algorithm for the period 1957-2004. Blue line indicates model fitted to data with the large (1963, 1981 and 1985) cohorts removed.